

Are GeV and TeV spectra connected? the case of Galactic γ -ray sources

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To understand Galactic objects that emits GeV-TeV emission, a spatial correlation study between the Fermi bright source catalog [1] and TeV source population was carried out in [2], finding that a significant number of very high-energy (VHE; $E > 100$ GeV) sources are also emitting at GeV energies. We extended our previous study utilizing the first Fermi catalog (1FGL) sources [3]. A cross-correlation comparison of the 1FGL sources was carried out with the VHE γ -ray sources in the literature as of May 2011. While it is found that a significant number of VHE γ -ray sources were also detected in the GeV band, the GeV-TeV spectra of some of these spatially coincident sources cannot be described by a single spectral component. While some of these cases are γ -ray pulsars accompanied by VHE γ -ray emitting nebulae, we present cases where the 100 MeV to multi-TeV spectra of coincident 1FGL/VHE source pairs do not seem to be well fit by a single spectral component.

I. INTRODUCTION

During the last decade, many different kinds of astrophysical objects in our Galaxy were discovered at photon energies above 100 MeV: pulsars (PSRs), pulsar wind nebulae (PWNe), supernova remnants (SNRs), high-mass X-ray binaries (HMXBs), and one H II region. They were all made by utilizing the high-energy (HE; 30 MeV–100 GeV) and very high-energy (VHE; 100 GeV–100 TeV) γ -ray experiments including current generation of imaging atmospheric Cherenkov telescopes (IACTs) H.E.S.S., MAGIC, and VERITAS, and the Large Area Telescope (LAT) aboard the Fermi satellite.

More than 100 sources are now known at VHE γ -ray energies and 1451 sources are listed in the first Fermi LAT catalog, comparing with ~ 10 VHE γ -ray sources and ~ 300 HE γ -ray sources around the turn of the century. Given the large number of sources, we follow previous studies [2, 4] and compare the HE and VHE source positions, as an important step to identify a group of sources emitting both in the HE and VHE bands.

II. SPATIAL COINCIDENCE STUDY

We cross-correlated the 1FGL source centroid positions with VHE γ -ray source centroid positions. Only sources that are not associated with an extragalactic source were considered. Using the same manner as described in [2], the VHE source extent and 95% uncertainty in the 1FGL source centroids are taken into account. All first Fermi/LAT catalog sources are assumed to be point sources as in [3]. Those sources with an ending ‘c’ should be regarded with caution given

the imperfect knowledge of the diffuse γ -ray background [3]. In total we identified 31 1FGL sources that are spatially coincident with one VHE source. In addition, the VHE source in the Westerlund 1 region, which are $\sim 0.6^\circ$ extended, is found to be spatially coincident with three 1FGL sources. HESS J1809–193 is coincident with two 1FGL sources. The list of these 1FGL-VHE source pairs are presented in Table I.

Based on pulsar timing information and dedicated efforts described in the corresponding literature, as well as spatial coincidences, the 1FGL sources in the list of coincidences include several classes: 2 HMXBs (LS I +61° 303 and LS 5039), 8 PSRs, 4 SNRs (IC 443, W28, W49B, W51C), 2 PSR/PWN (Crab and Vela), 6 SNR/PWN candidates, one H II region, and 13 unassociated sources.

III. GEV-TEV SPECTRA

The GeV spectral points are taken from the 1FGL catalog where point source analysis was used, while the VHE spectra shown are the best-fit power law taken from the respective literature.

We identify several cases of which the 0.1–100 GeV spectra and the VHE spectra cannot be described by a single spectral components, as shown in Figs 1–5. The flux in the five energy bands in [3] are plotted together with the best-fit power law in the VHE range. In several other cases, the GeV emission come from a γ -ray pulsar, i.e., those 1FGL source identified as a pulsar, that shows cutoff at several GeV and VHE emission mostly likely come from the associated VHE γ -ray emitting PWN. We only present cases where the 1FGL source is not identified as a pulsar.

IV. CASES OF SPECTRAL ‘MIS-MATCH’

We found five VHE sources that are spatially coincident with a 1FGL source but the GeV–TeV spectra are incompatible with a single spectral component: HESS J0852–463, HESS J1614–518, HESS J1702–420, HESS J1809–193, and HESS J1848–018. The cases presented here might represent a group of GeV/TeV sources where the spectral mis-matches indicate different radiations working at different energies or that radiation comes from different parts of a γ -ray source. Further studies of these spectral mis-match GeV/TeV spatially coincident cases are encouraged.

V. CONCLUSION

In this study, it is found that a significant number of VHE sources are spatially coincident with a counterpart in the first Fermi/LAT catalog, establishing a population of sources that emit both in the HE and VHE energy bands. This confirms our previous as-

essment using the Fermi bright source list [2].

However, the GeV–TeV spectra of some of these spatially coincident sources cannot be described by a single spectral component. While some of these cases are γ -ray pulsars accompanied by VHE γ -ray emitting nebulae, we highlight five cases where the 100 MeV to multi-TeV spectra of coincident 1FGL/VHE source pairs do not seem to be well fit by a single spectral component.

Notes added in proof: The second Fermi catalog has been released after the conference. We note that one of the coincidence pairs, 1FGL J1702.4–4147c, does not have a 2FGL counterpart.

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TABLE I: 1FGL sources with spatially coincident VHE counterpart as of May 2011. The class denoted ‘SNR/PWN’ means SNR/PWN candidates, according to [3].

1FGL source	association	class	l ($^{\circ}$)	b ($^{\circ}$)	VHE γ -ray source	association	l ($^{\circ}$)	b ($^{\circ}$)	extension ($^{\circ}$)	ref
J0240.5+6113	LS I+61 303	HMXB	135.66	1.08	VER J0240+612	LS I +61 303	135.70	1.08	pt src	[5]
J0534.5+2200	Crab	PSR/PWN	184.56	-5.76	HESS J0534+220	Crab nebula	184.56	-5.78	pt src	[6]
J0617.2+2233	IC 443	SNR	189.08	3.07	VER J0616.9+2230	IC 443	189.08	2.92	0.16	[7, 8]
J0835.3-4510	Vela	PSR/PWN	263.56	-2.77	HESS J0835-455	Vela X	263.86	-3.09	0.43	[9]
J0854.0-4632		SNR/PWN	266.64	-1.09	HESS J0852-463	RX J0852.0-4622	266.28	-1.24	1.0	[10]
J1023.0-5746	PSR J1023-5746	PSR	284.17	-0.41	HESS J1023-575	PSR J1023-5746/Wd 2	284.22	-0.40	0.18	[11]
J1418.7-6057	PSR J1418-6058	PSR	313.34	0.11	HESS J1418-609	G313.3+0.1 (Rabbit)	313.25	0.15	0.06	[12]
J1420.1-6048	PSR J1420-6048	PSR	313.50	0.20	HESS J1420-607	PSR J1420-6048	313.56	0.27	0.07	[12]
J1501.6-4204		SNR/PWN	327.30	14.54	HESS J1502-421	SN 1006 SW	327.35	14.48	0.13	[13]
J1503.4-5805c		Unid	319.67	0.42	HESS J1503-582	FVW 319.8+0.3?	319.62	0.29	0.26	[14]
J1614.7-5138c		Unid	331.69	-0.49	HESS J1614-518		331.52	-0.58	0.2	[15]
J1640.8-4634c		SNR/PWN	338.29	-0.06	HESS J1640-465	G338.3-0.0	338.32	-0.02	0.05	[15]
J1648.4-4609c	PSR J1648-4611	PSR	339.47	-0.79	Westerlund 1 region		339.55	-0.40	~ 0.9	[16]
J1649.3-4501c		Unid	340.44	-0.18	same as above					
J1651.5-4602c		Unid	339.91	-1.12	same as above					
J1702.4-4147c		Unid	344.45	0.00	HESS J1702-420	PSR J1702-4128	344.26	-0.22	0.3	[17]
J1707.9-4110c		Unid	345.56	-0.44	HESS J1708-410		345.67	-0.44	0.08	[17]
J1709.7-4429	PSR B1706-44	PSR	343.10	-2.69	HESS J1708-443	PSR B1706-44/G343.1-2.3	343.06	-2.38	0.29	[18]
J1711.7-3944c		SNR/PWN	347.15	-0.19	HESS J1713-397	RX J1713.7-3946	347.28	-0.38	0.25	[19]
J1718.2-3825	PSR J1718-3825	PSR	349.00	-0.40	HESS J1718-385	PSR J1718-3825?	348.83	-0.49	0.015	[20]
J1745.6-2900c		SNR/PWN	359.94	-0.05	HESS J1745-290	Sgr A*/G359.95-0.04	359.94	-0.04	pt src	[21]
J1800.5-2359c	W28-A2	H II region	5.95	-0.37	HESS J1800-240B	W28-A2	5.90	-0.37	0.15	[22, 23]
J1801.3-2322c	W28	SNR	6.57	-0.22	HESS J1801-233	W28	6.66	-0.27	0.17	[22, 23]
J1805.2-2137c		SNR/PWN	8.55	-0.14	HESS J1804-216	W30/PSR J1803-2137?	8.40	-0.03	0.20	[15]
J1808.5-1954c		Unid	10.43	0.03	HESS J1809-193	PSR J1809-1917?	10.92	0.08	0.53	[20]
J1810.9-1905c		Unid	11.42	-0.08	same as above					
J1826.2-1450	LS 5039	HMXB	16.88	-1.29	HESS J1826-148	LS 5039	16.90	-1.28	pt src	[24]
J1837.5-0659c		Unid	25.13	-0.12	HESS J1837-069		25.18	-0.12	$7.2' \times 3'$	[15]
J1844.3-0309c		Unid	29.32	0.13	HESS J1843-033		~ 29.08	~ 0.16	~ 0.2	[25]
J1848.1-0145c		Unid	30.99	-0.08	HESS J1848-018		30.98	-0.16	0.32	[26]
J1907.9+0602	PSR J1907+0602	PSR	40.18	-0.89	HESS J1908+063	MGRO J1908+06	40.39	-0.79	0.34	[27]
J1910.9+0906c	W 49B	SNR	43.25	-0.16	W 49B region	W49B	43.26	-0.19	pt src	[28, 29]
J1913.7+1007c		Unid	44.48	-0.28	HESS J1912+101	PSR J1913+101	44.36	-0.08	0.27	[30]
J1922.9+1411	W 51C	SNR	49.12	-0.38	HESS J1923+141	W51	49.14	-0.6	~ 0.15	[31, 32]
J2020.0+4049		Unid	78.37	2.53	VER J2019+407	γ Cygni SNR?	78.33	2.54	0.16×0.11	[33]
J2032.2+4127	PSR J2032.2+4127	PSR	80.22	1.03	TeV J2032+4130		80.23	1.10	0.10	[34]

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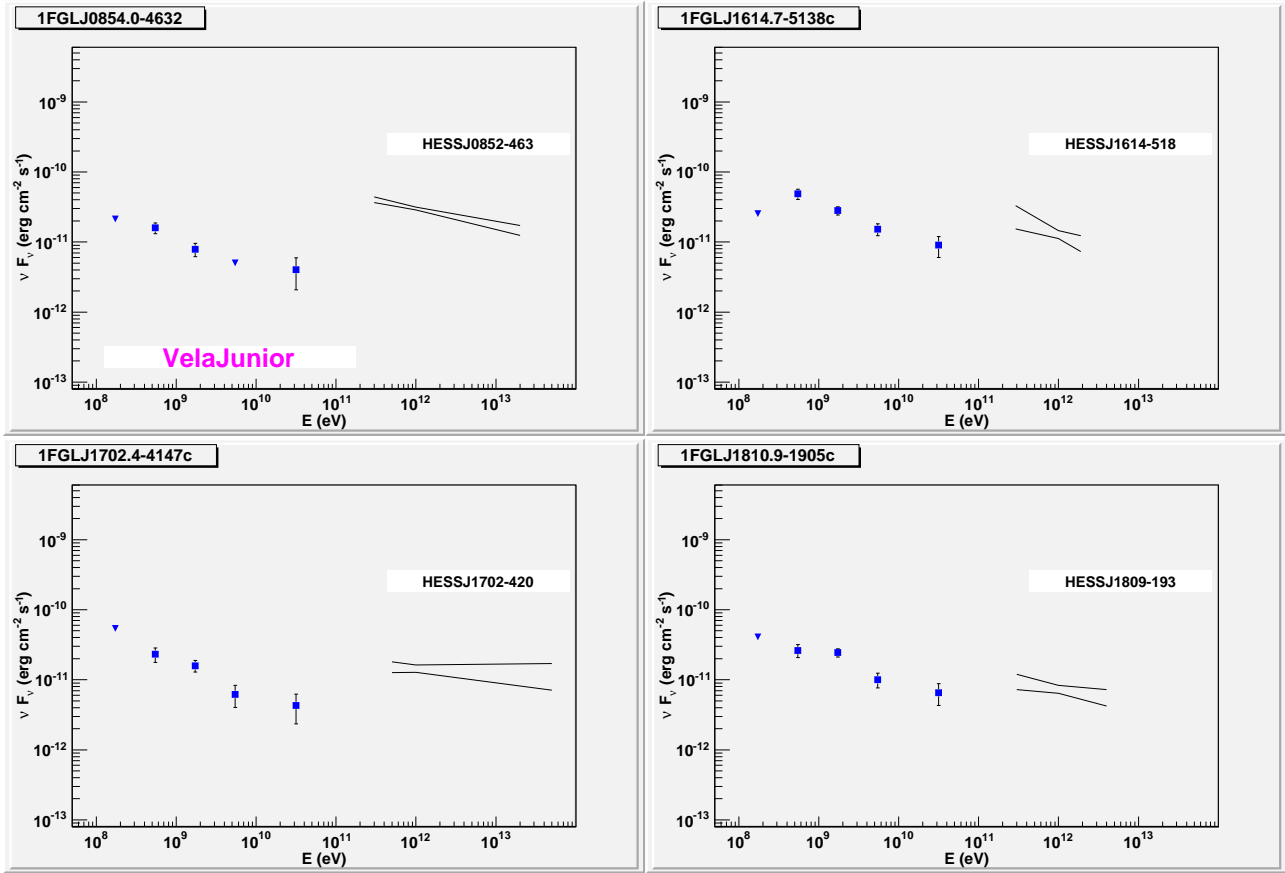


FIG. 1: The 100 MeV to several tens TeV spectra of four spatially coincident but spectrally ‘mis-match’ 1FGL/VHE source pairs

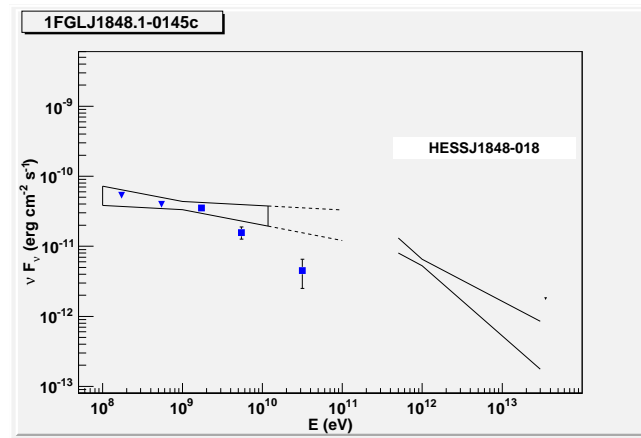


FIG. 2: The 100 MeV to several tens TeV spectra of 1FGL J1848.1-0145c and HESS J1848-018. 1FGL J1848.1-0145c has a 0FGL counterpart whose best-fit power law is also shown.